

Core Noise: overview and upcoming LDI combustor test

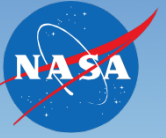
Lennart S. Hultgren, NASA Glenn Research Center, Cleveland, OH 44135

**Presented at the Acoustics Technical Working Group Meeting
Hampton, Virginia, October 23-25, 2012**

Summary

This presentation is a technical summary of and outlook for NASA-internal and NASA-sponsored external research on core (combustor and turbine) noise funded by the Fundamental Aeronautics Program Fixed Wing Project. The presentation covers: the emerging importance of core noise due to turbofan design trends and its relevance to the NASA N+3 noise-reduction goal; the core noise components and the rationale for the current emphasis on combustor noise; and the current and planned research activities in the combustor-noise area. Two NASA-sponsored research programs, with particular emphasis on indirect combustor noise, “Acoustic Database for Core Noise Sources”, Honeywell Aerospace (NNC11TA40T) and “Measurement and Modeling of Entropic Noise Sources in a Single-Stage Low-Pressure Turbine”, U. Illinois/U. Notre Dame (NNX11AI74A) are briefly described. Recent progress in the development of CMC-based acoustic liners for broadband noise reduction suitable for turbofan-core application is outlined. Combustor-design trends and the potential impacts on combustor acoustics are discussed. A NASA GRC developed nine-point lean-direct-injection (LDI) fuel injector is briefly described. The modification of an upcoming thermo-acoustic instability evaluation of the GRC injector in a combustor rig to also provide acoustic information relevant to community noise is presented.

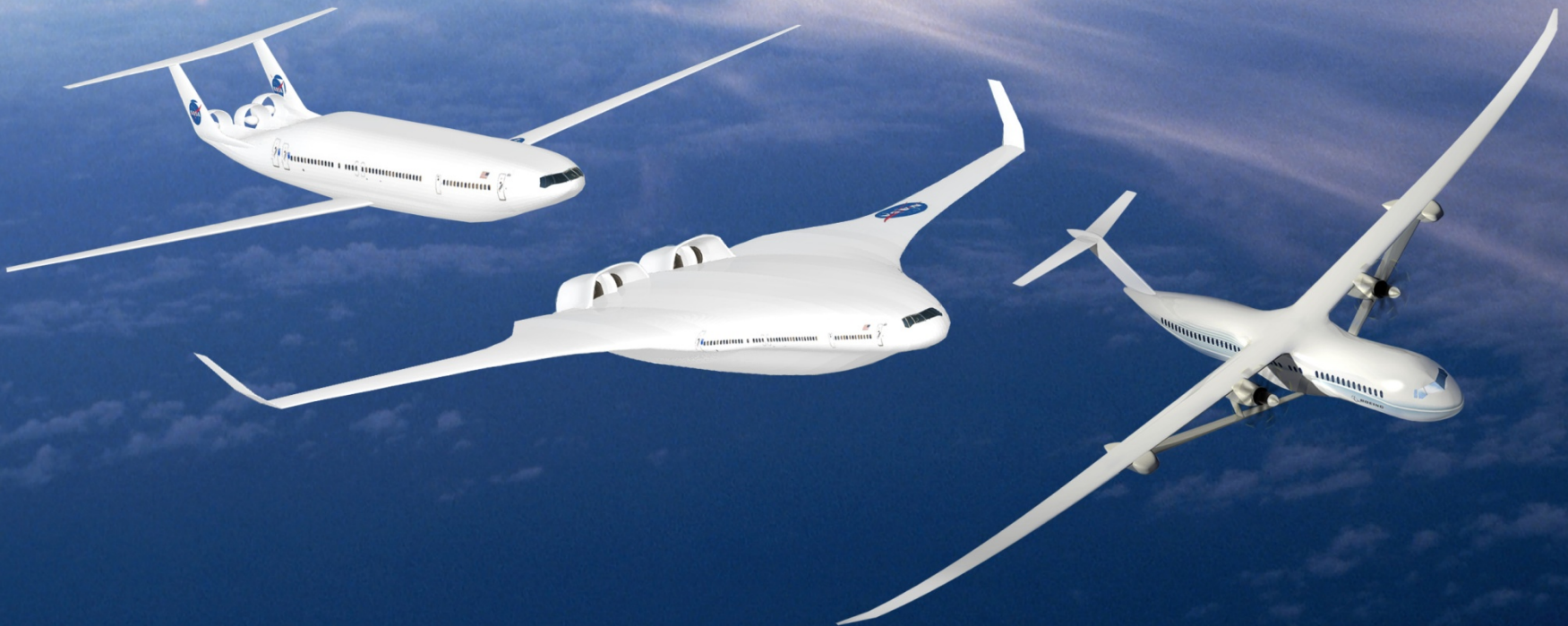
The NASA Fundamental Aeronautics Program has the principal objective of overcoming today's national challenges in air transportation. The reduction of aircraft noise is critical to enabling the anticipated large increase in future air traffic. The Quiet Performance Research Theme of the Fixed Wing Project aims to develop concepts and technologies to dramatically reduce the perceived community noise attributable to aircraft with minimal impact on weight and performance.



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.... Quiet Performance – High-Efficiency Gas-Generator Technical Challenge

Lennart S. Hultgren
NASA Glenn Research Center
Cleveland, OH 44135



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NASA Fundamental Aeronautics Program
Fixed Wing Project



- ❑ Current Core-Noise (combustor & turbine) Prediction Tools
 - based on empiricism and rooted in 1970s technology
 - ❖ some updates in 1990s & 2000s
 - dated and of unknown applicability to emerging N+3 core designs
- ❑ Core Noise – What Is It & Why Does It Matter
 - core noise & its increasing importance due to turbofan design trends
 - high-efficiency, small gas generator – N+3 subsystem research
 - core noise must be addressed to meet N+3 noise goals
- ❑ NASA Core-Noise Experiments, Modeling & Prediction
 - in-house (GRC) modeling and data analysis
 - LaRC/GRC: liners for broadband core-noise reduction
 - 2 core-noise FW NRA R5 efforts (with Honeywell and UIUC/UND)
 - Lean-Direct-Injection (LDI) combustor test – plans and objectives

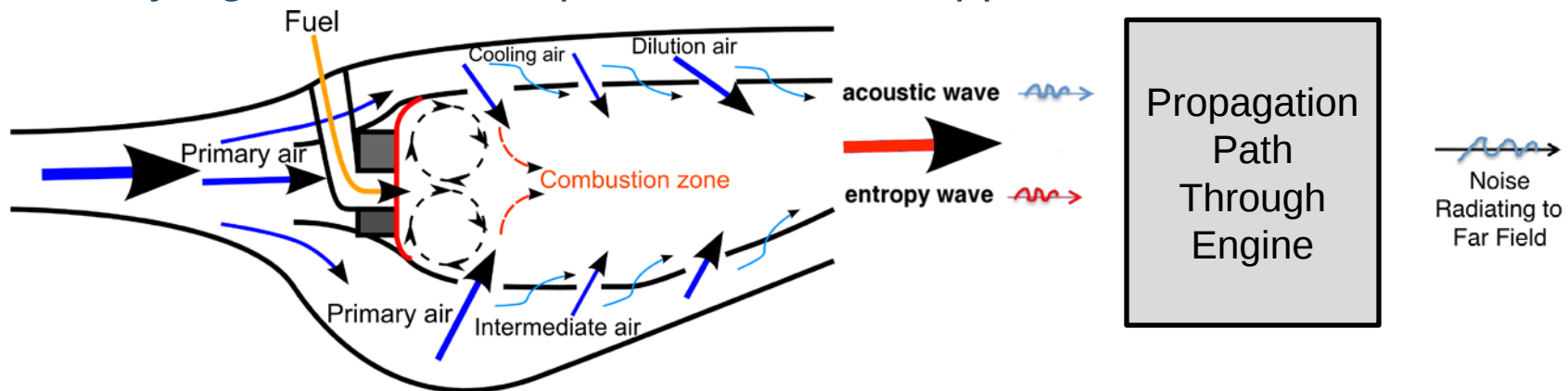
Current tools: dated and applicability to emerging N+3 designs unknown

Core Noise

.... what are its components?



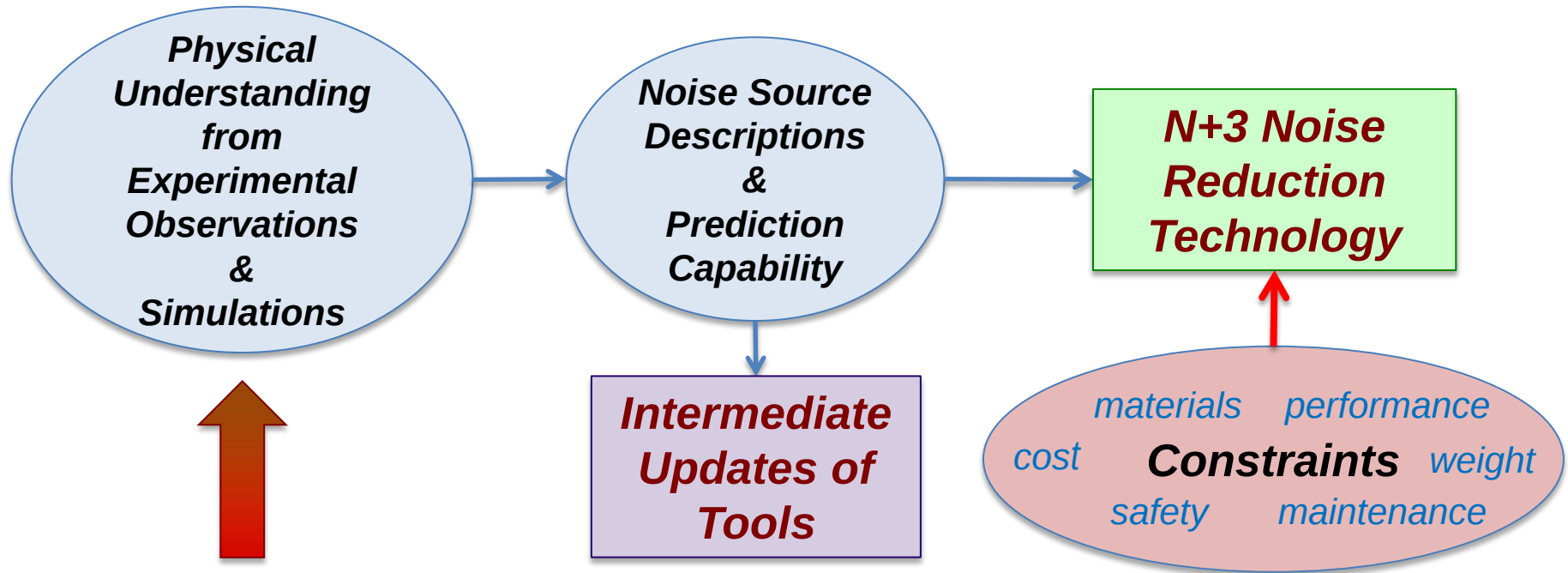
- ❑ Engine-Internal Propulsion Noise Other Than Fan and Jet
 - compressor noise – tonal in blade-passing frequency range (kHz)
 - combustor noise – low frequency (< 1 kHz) broadband
 - turbine noise – tonal in blade-passing frequency range (kHz)
- ❑ Combustor and Turbine Noise Most Important
- ❑ NASA FAP FW Emphasis on Combustor Noise
 - limited resources
 - judged to be most potential show stopper for noise reduction effort



Must fully understand noise-source structure in combustor, effects of propagation path through engine, and implications of design trends

NASA Core-Noise Activities

... research in support of N+3 goals

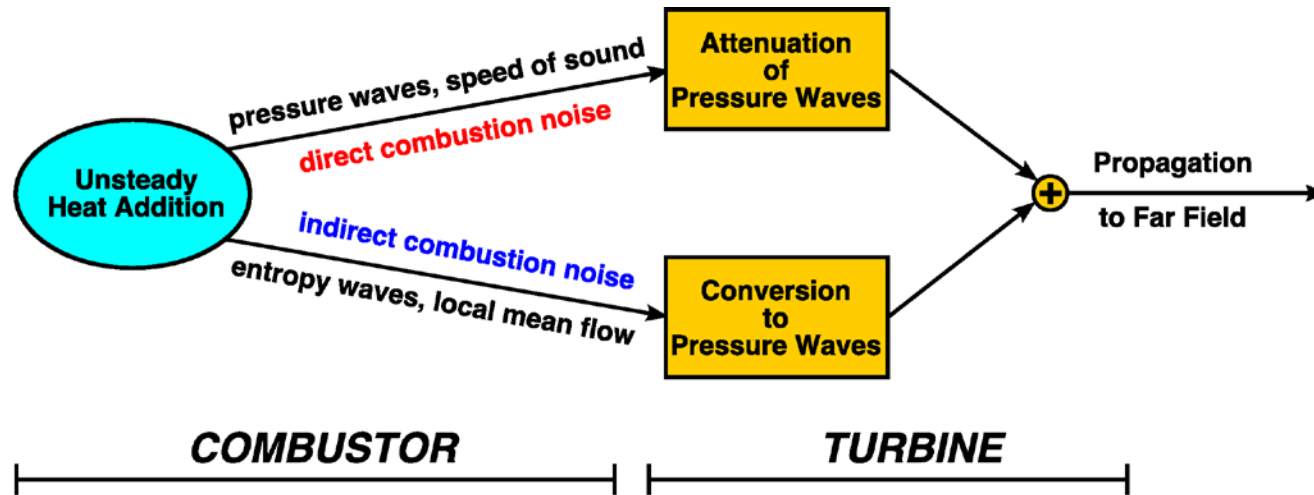


- ❑ Core Noise Must Be Addressed to Ensure N+3 Goals
- ❑ N+3 Designs Likely Outside of Current Noise-Model Parameter Space
- ❑ Focused Research to Enable Advanced Subsystems That Meet NASA's N+3 Technical Challenges – High-Efficiency Gas Generator

*Reduce perceived community noise attributable to aircraft
with minimal impact on weight and performance*

NASA FAP FW Combustor-Noise Activities

... ongoing NASA efforts under Quiet-Performance Research Theme



□ Direct and Indirect Contributions to Combustor Noise

- same low frequency range
- relative importance uncertain
- source-separation analysis: indirect noise present in real-engine data

J. H. Miles: AIAA 2008-0050; J. Propulsion and Power **25** (1), 2009;

J. Propulsion and Power **26** (2&5), 2010

- both FW NRA R5 efforts designed to yield significant physical insight

Dual paths of combustor noise (direct & indirect) – balance may change

High-Efficiency Gas Generator NRA R5 Activities

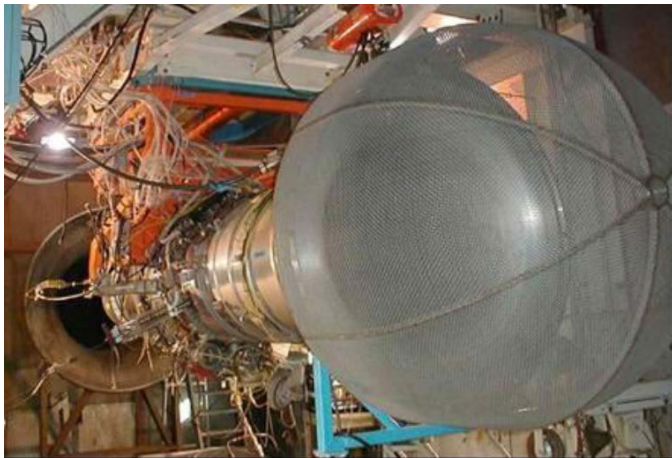
... Quiet Performance focus and technical content



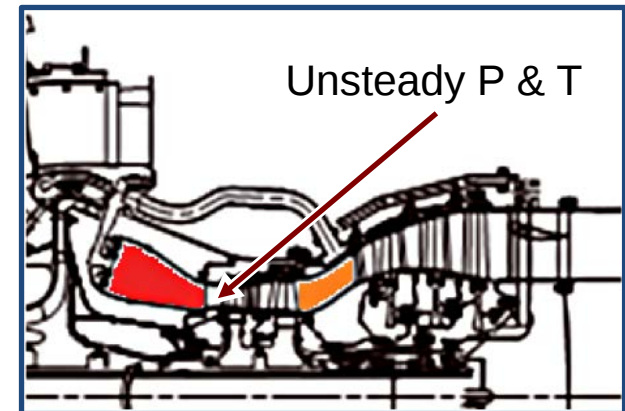
Focus: Improve understanding of the core noise generation process and develop databases for code & model development & validation

Technical Content:

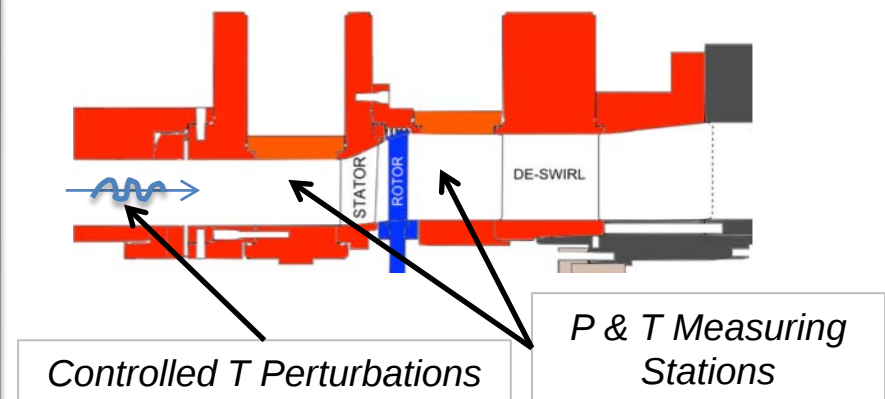
- Honeywell Aerospace
 - measurements in full-scale engine



Honeywell TECH977 Turbofan in Test Cell



- U. of Illinois Urbana-Champaign/U. of Notre Dame
 - rig experiments & simulation



Focused N+3 work with intermediate impact as understanding is improved

Initial Evaluation of CMC Core Acoustic Liner

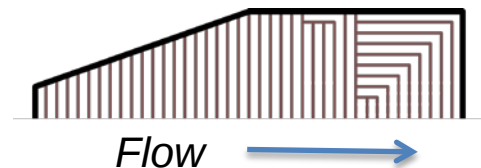
... high-temperature, low-weight, engine-internal, acoustic liner



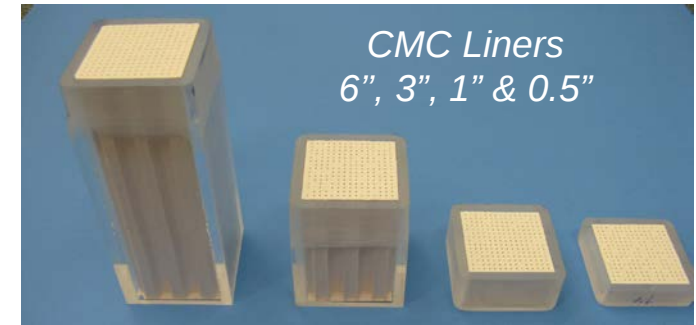
□ LaRC/GRC effort

- *objective:* develop broadband liners suitable for harsh engine environment
- *approach:* design using conventional models and evaluate effects of CMC porosity through testing in the LaRC Normal Incidence Tube facility
- *results:* prediction method validated
- *significance:* conventional methods work OK for CMC liner design
- *now:* broadband liner designed for upcoming LaRC Grazing Flow Impedance Tube testing

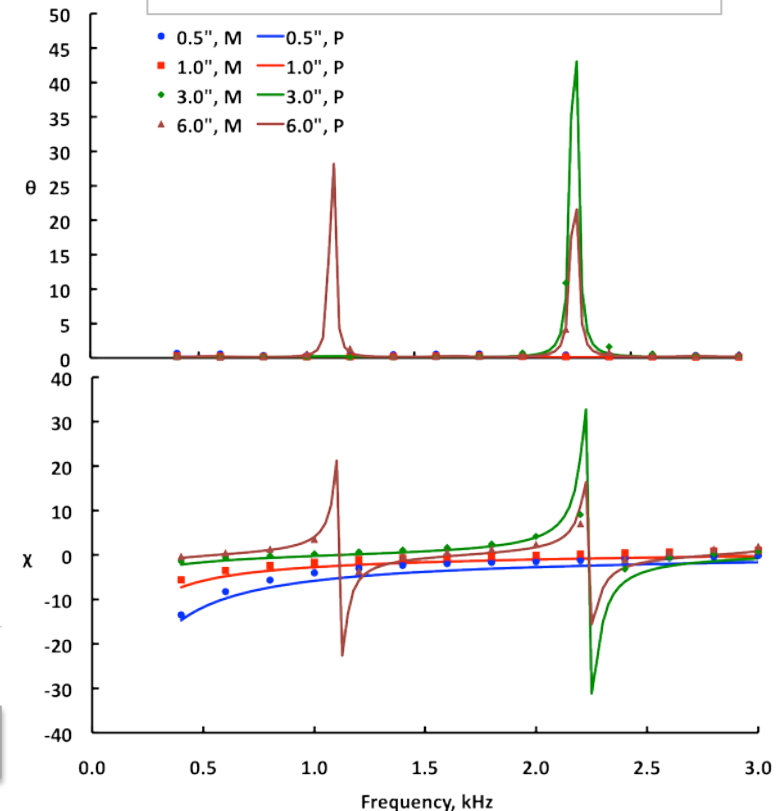
Notional cross section of variable-depth liner



POC: LaRC/Michael Jones & GRC/Doug Kiser



Measurement vs. Prediction



NASA GRC LDI Combustor Test

... Combustor-design trends and potential impact on acoustics



❑ Combustor Design Goals

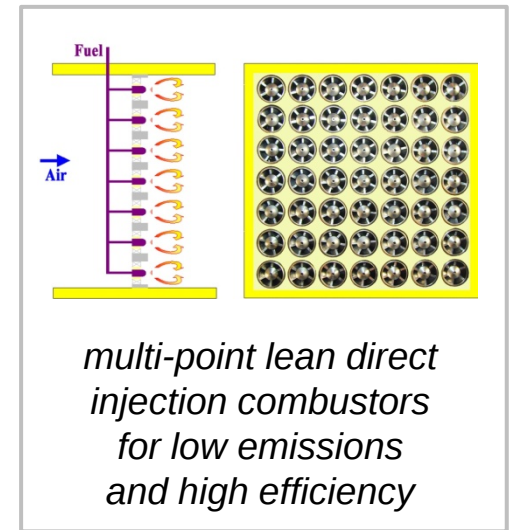
- higher performance – efficiency and energy release
- low emissions and noise
- fuel flexibility

❑ Requirements

- high levels of mixing and uniformity
- lean burning
- no combustion instability

❑ Potential Impacts on Combustor Acoustics

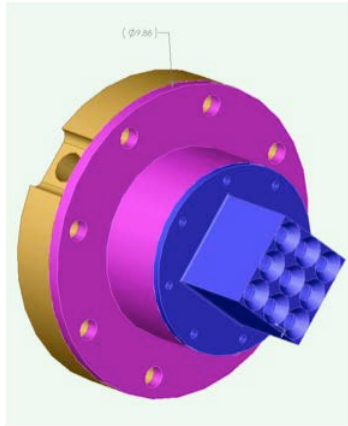
- premixed-combustion trend could change frequency range & peak
- balance between direct and indirect combustor noise could change
- active/passive combustion-instability control strategy could increase noise levels even in the absence of instability



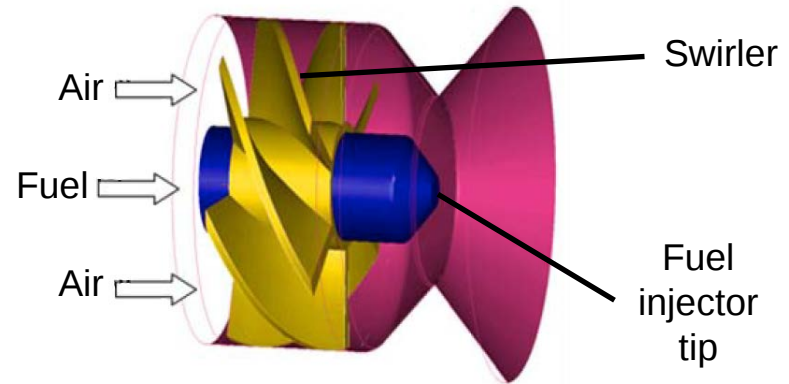
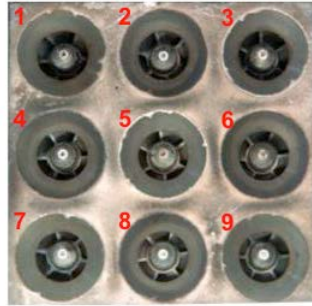
Need to understand impact of combustor-design changes

NASA GRC LDI Combustor Test

... thermo-acoustic characterization of GRC nine-point fuel injector



GRC lean, premix, nine-point fuel injector

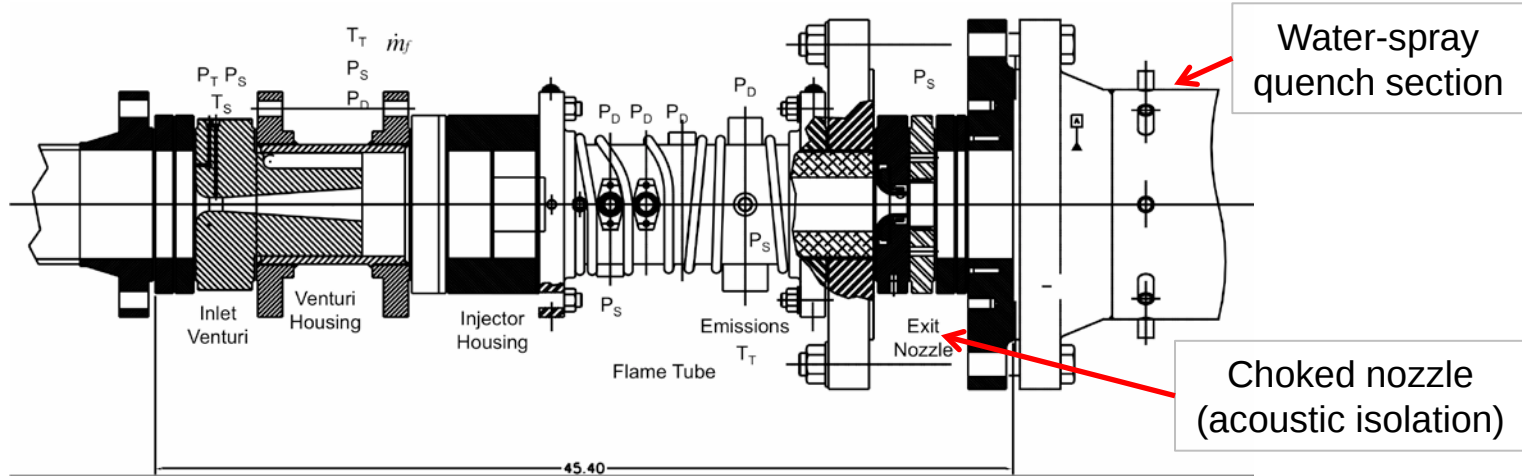


Single-element LDI geometry

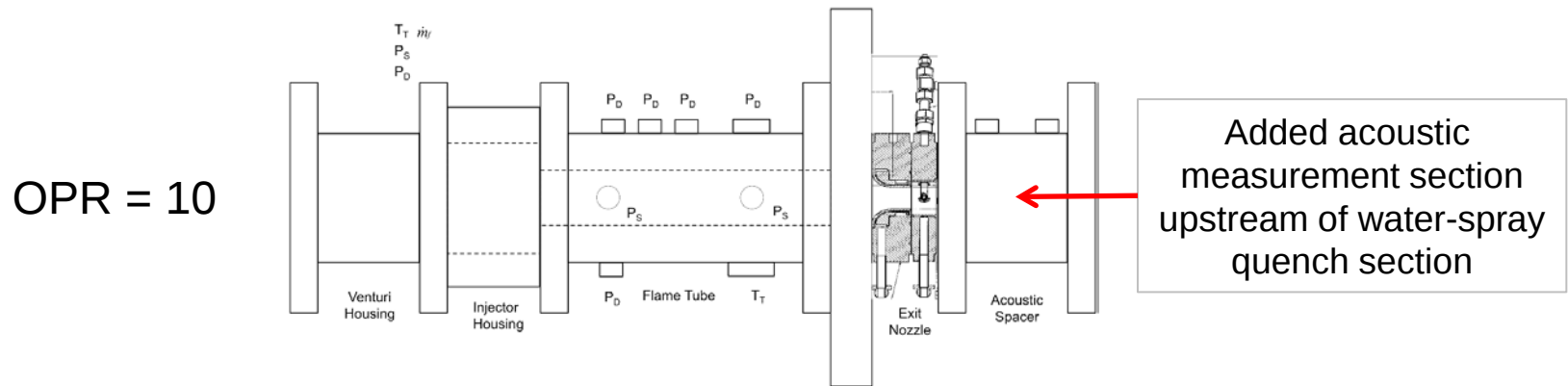
- ❑ Potential to Achieve Emissions & Efficiency Goals
 - demonstrated through experimental and numerical studies
- ❑ Thermo-Acoustic Evaluation Planned to Start in FY13
 - investigate occurrence of combustion instability
 - evaluate the need for mitigation strategies & recommend action
 - GRC Combustion Branch activity – POC: RTB/Waldo Acosta
- ❑ Combustor Noise Investigation Being Added to Plans
 - GRC Acoustics Branch input – POC: RTA/Jeffrey H. Miles

NASA GRC LDI Combustor Test

... combustor-noise aspects of GRC nine-point fuel injector test



Schematic of original configuration of the Stand 2 facility in the CE-5B test cell at NASA GRC



Schematic of modified configuration of the Stand 2 facility in the CE-5B test cell at NASA GRC

Facility modifications to enable noise-source diagnostics

NASA GRC LDI Combustor Test

... operation and instrumentation



- ❑ Jet-A/JP-8 Primary Fuel – Alternate Fuels If Available
- ❑ Operate with Choked Exit Nozzle
 - acoustic isolation of flame tube from downstream (quench section)
- ❑ Dynamic Pressure Sensors
 - 4 in-line axial locations, 2 circumferential locations in flame tube
 - 2 in-line axial locations in downstream measurement section
- ❑ Mean Properties
 - various sensors to fully characterize combustor operation
 - inlet venturi, flame tube, injector, fuel flow, exit nozzle
 - total and static pressures, temperatures, emissions, etc.
- ❑ Potential: High-Frequency Fuel-Flow Actuation For Control
- ❑ Sufficiently Long Time Sequences for Source Analysis

Objective: illuminate impact of combustor-design trends on noise-sources

Summary

.... core-noise research in support of N+3 goals



- ❑ Current Core-Noise Prediction Tools Are Dated
- ❑ Core Noise Must Be Addressed to Ensure N+3 Goals
- ❑ Prediction Tools Are Updated As Understanding Improves
- ❑ Need to Understand Impact of Combustor-Design Changes
 - lean direct injection and other low-emission designs
 - alternate fuels
- ❑ Need Improved Turbine & Exit-Nozzle Transfer Functions
 - Schuster & Lieber 2006; Karchmer 1983
 - physics-based approach – holds more promise than empiricism

